Effects of CO_2 on coral growth and calcification

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Introduction

- The ocean is currently taking up anthropogenic CO_2 at the rate of 1.5 ± 0.6 Gt C yr^{-1} (Quay et al. 2003 Global Biogeochemical Cycles).
- This input is causing measurable changes in the carbonate chemistry of the surface ocean observed at the Hawaiian ocean time series station (± 95 CI).
  - $\delta^{13}C$ of DIC — -0.16 ± 0.02 ‰ per decade
  - pH — -0.03 ± 0.01 pH units per decade
  - pCO_2 — 27 ± 11 µatm per decade
  - HCO_3^- — 27 ± 9 µmol kg^{-1} per decade
  - CO_3^{2-} — -13 ± 4 µmol kg^{-1} per decade
  - Ω_{arag} — -0.22 ± 4 per decade (Ω is relative solubility product for aragonite defined as $[Ca^{2+}][CO_3^{2-}]/K'_{sp}$)

Possible effects of these chemcial changes on reef processes

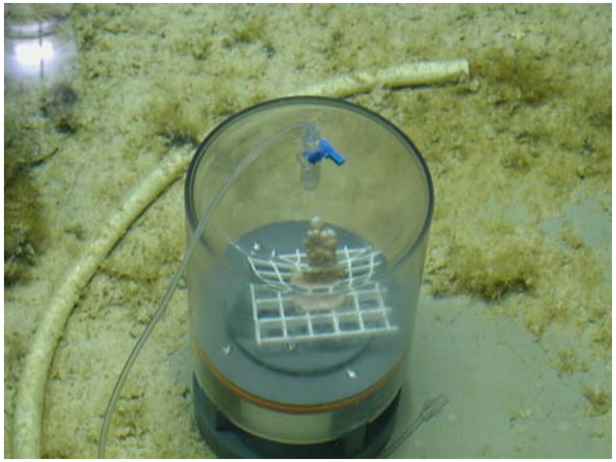
- Increased photosynthesis by algal symbionts if they are CO_2 or HCO_3^- limited.
- Increased calcification and skeletal growth of corals if they utilize HCO_3^- and are carbon limited.
- Decreased calcification and skeletal growth if corals utilize only CO_3^{2-} and are carbon limited.
- Increased growth of fleshy algae if they are CO_2 or HCO_3^- limited.
- As a result we might expect that the condition of corals to improve, worsen or not change.

Chemistry changes for 2-fold increase in atmospheric CO_2

	°C	TA	pCO_2	HCO_3^-	CO_3^{2-}	Ω_a	pH_{sw}
Present	25	2350	350	1764	239	3.80	8.09
2X Future	27	2350	700	1959	160	2.57	7.84
% change			100	11	-33	-32	-0.25 units

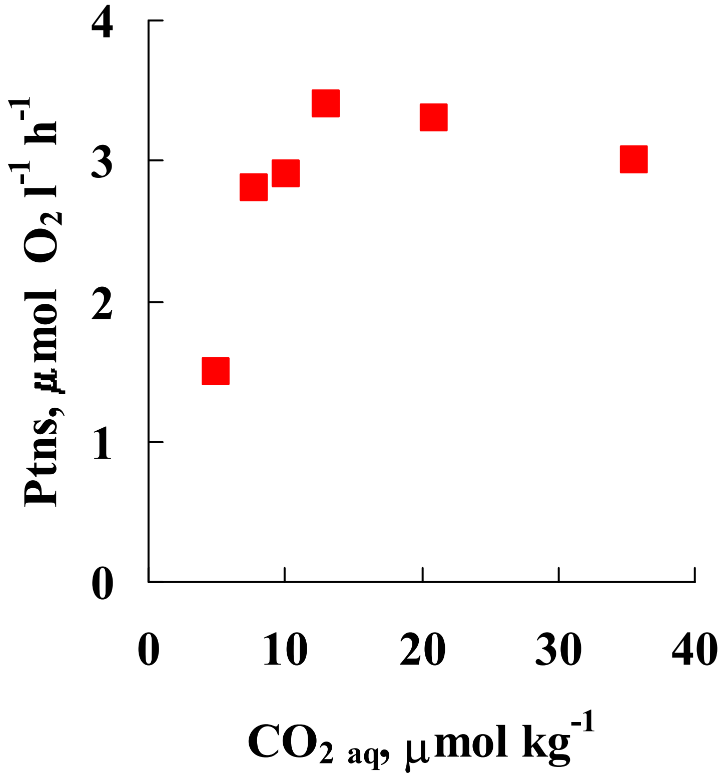
What happens to coral photosynthesis if CO_2 doubles?

A colony of *Montipora capitata* was placed in the chamber shown. Carbonate chemistry of the water was manipulated and the photosynthetic rate was determined from the increase in dissolved oxygen concentration over a three hour incubation period.



Summary of chemical conditions and photosynthetic response of *Montipora capitata*

TA, µmol kg^{-1}	DIC, µmol kg^{-1}	$CO_{2\ aq}$, µmol kg^{-1}	pH_{sw}	NP, µmol l^{-1} h^{-1}
832	697	5.0	7.91	1.5
1275	1102	7.8	7.92	2.8
1560	1327	10.1	7.90	2.9
2013	1792	13.1	7.91	3.4
3585	3213	21.0	7.96	3.3
6309	5696	35.6	7.97	3.0



Net photosynthesis saturates at a [CO_2] slightly above that of normal seawater.

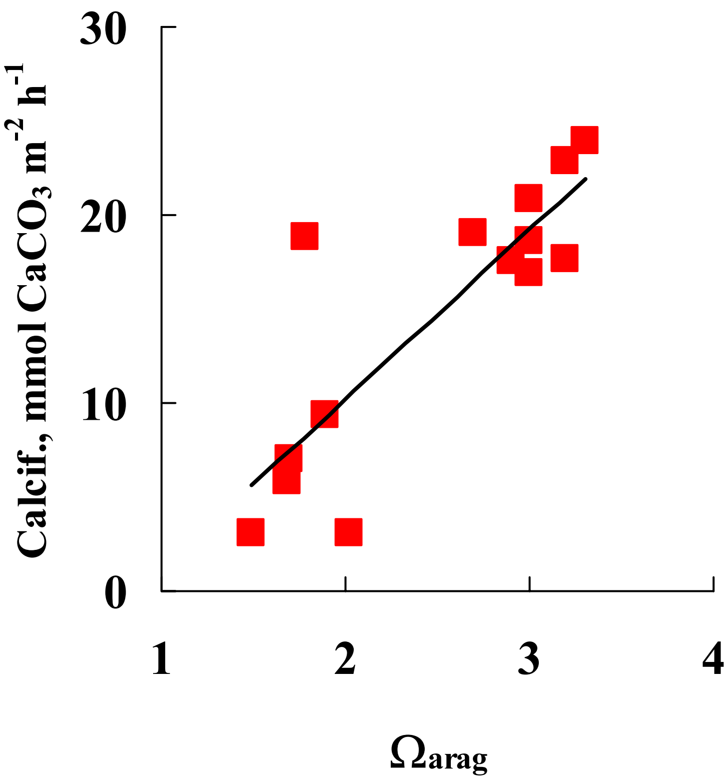
What happens to coral calcification if CO_2 is increased?

- Fragments of *Porites compressa* and *Montipora capitata* were collected near Cocconut Is. in Kaneohe Bay, HI and placed in a flume of flowing seawater. Corals received full natural sunlight.
- Each day the calcification rate of the assembled coral was measured for 1.5 hours with normal seawater or acidified seawater. On alternate days the treatments were reversed and the corals were exposed to acidified seawater first.

Response of corals in flume to an increase pCO_2 and drop in pH

	pCO_2	pH_{sw}	HCO_3	Ω_a
Normal SW	459	7.96	1691	3.01
Acidified SW	713	7.77	1693	1.95

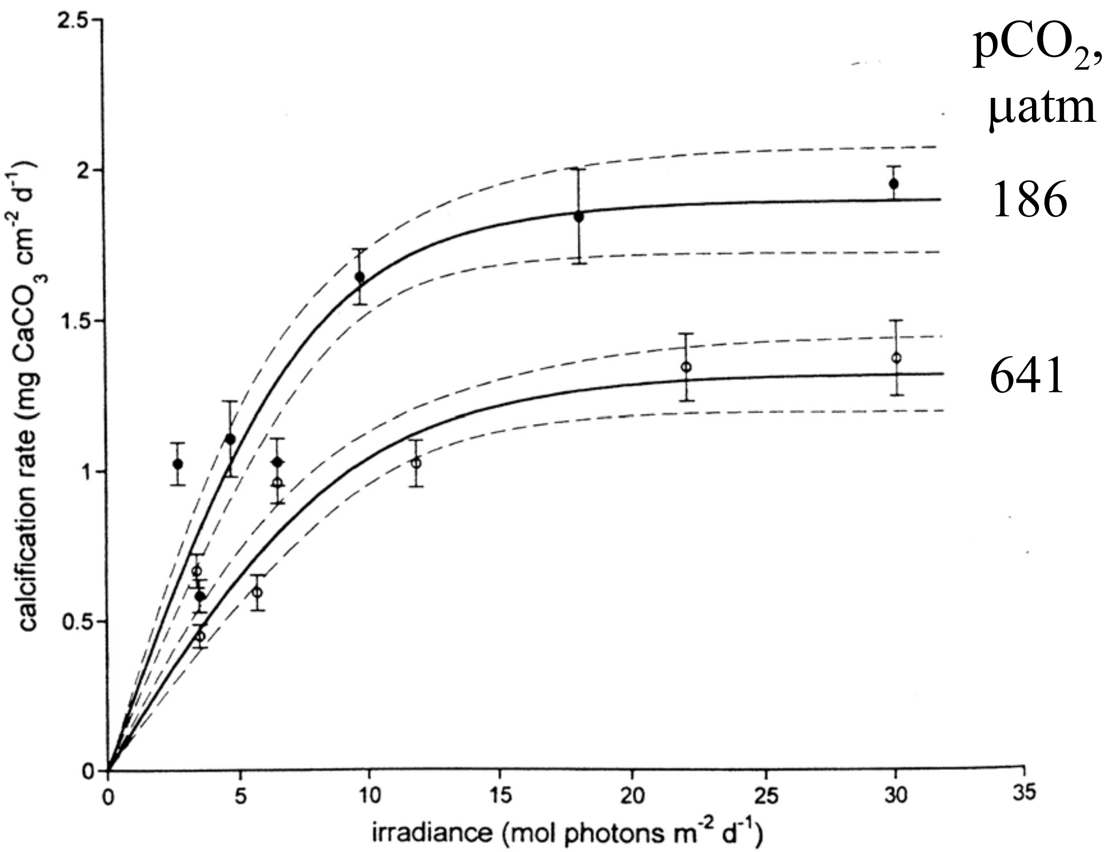
There was an immediate drop in calcification of 2-6 fold in all but one experiment in response to a 1.6-fold increase in $pCO_{2.}$



Skeletal growth of *Porites compressa* as function of CO_2 and light level

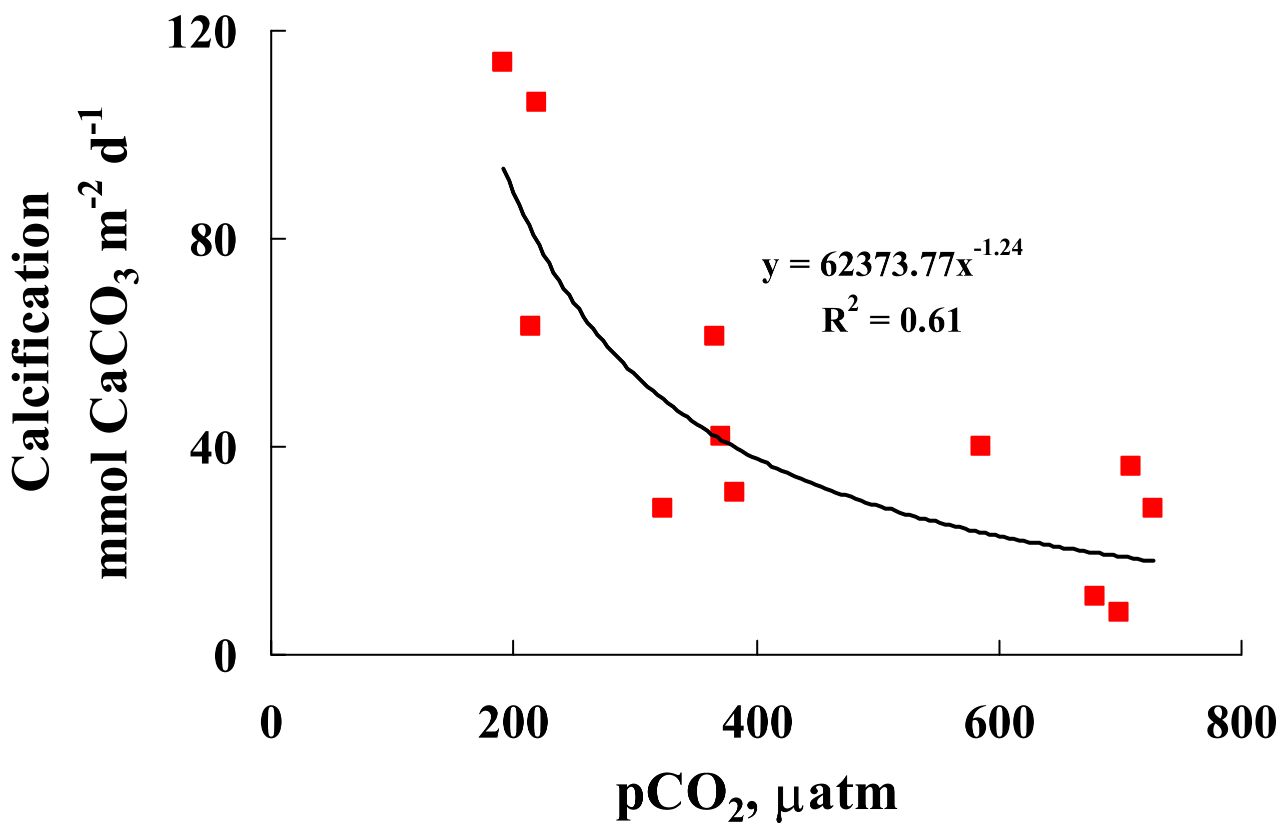
Elevated CO_2 depresses skeletal growth measured over a six-week period.

Effect is observed over a wide range of irradiance.

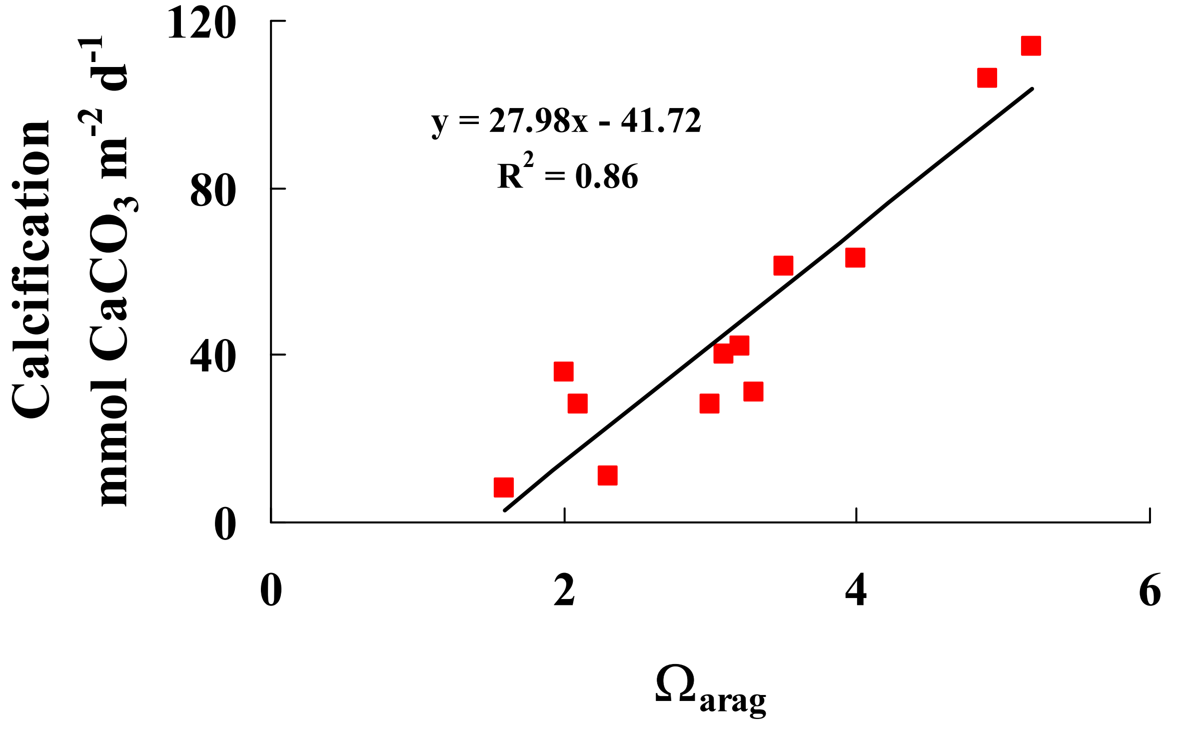


Marubini et al. 2001

Effect of CO_2 on Biosphere mesocosm community calcification

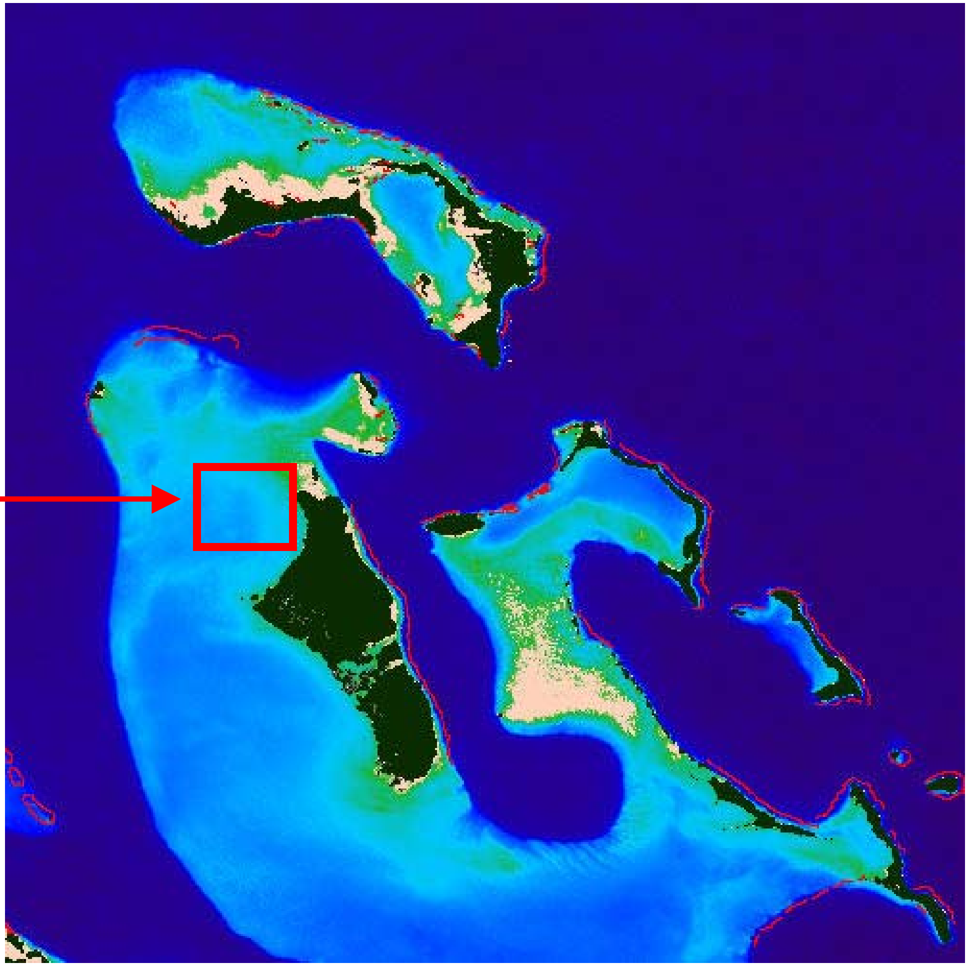


Saturation state controls calcification



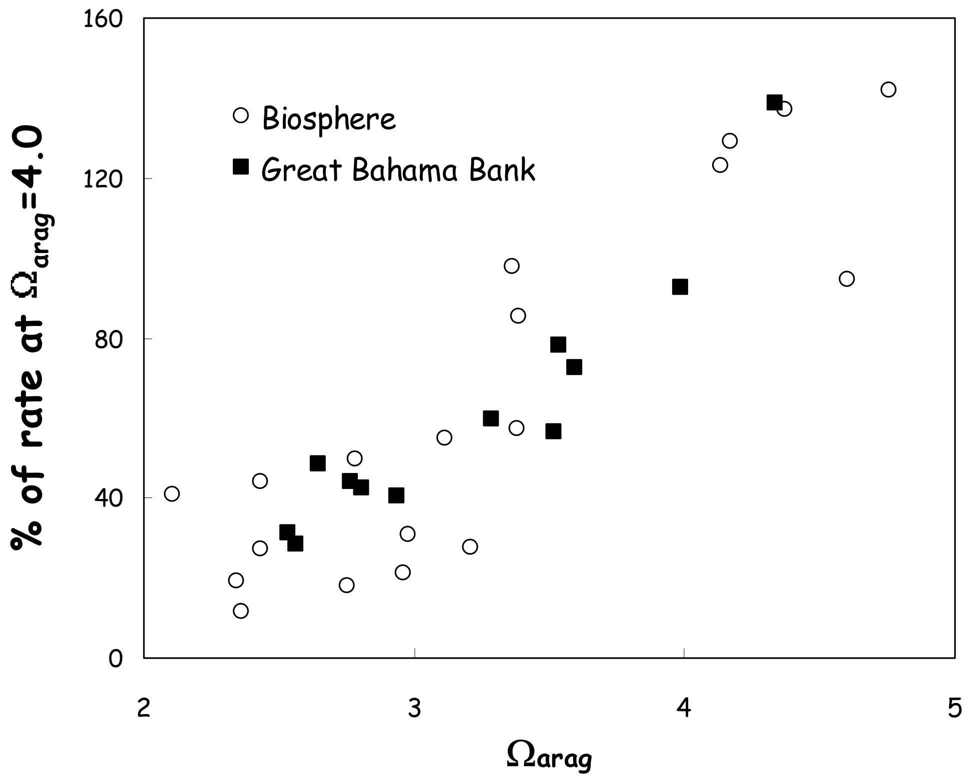
Great Bahama Bank

12,300 km^2



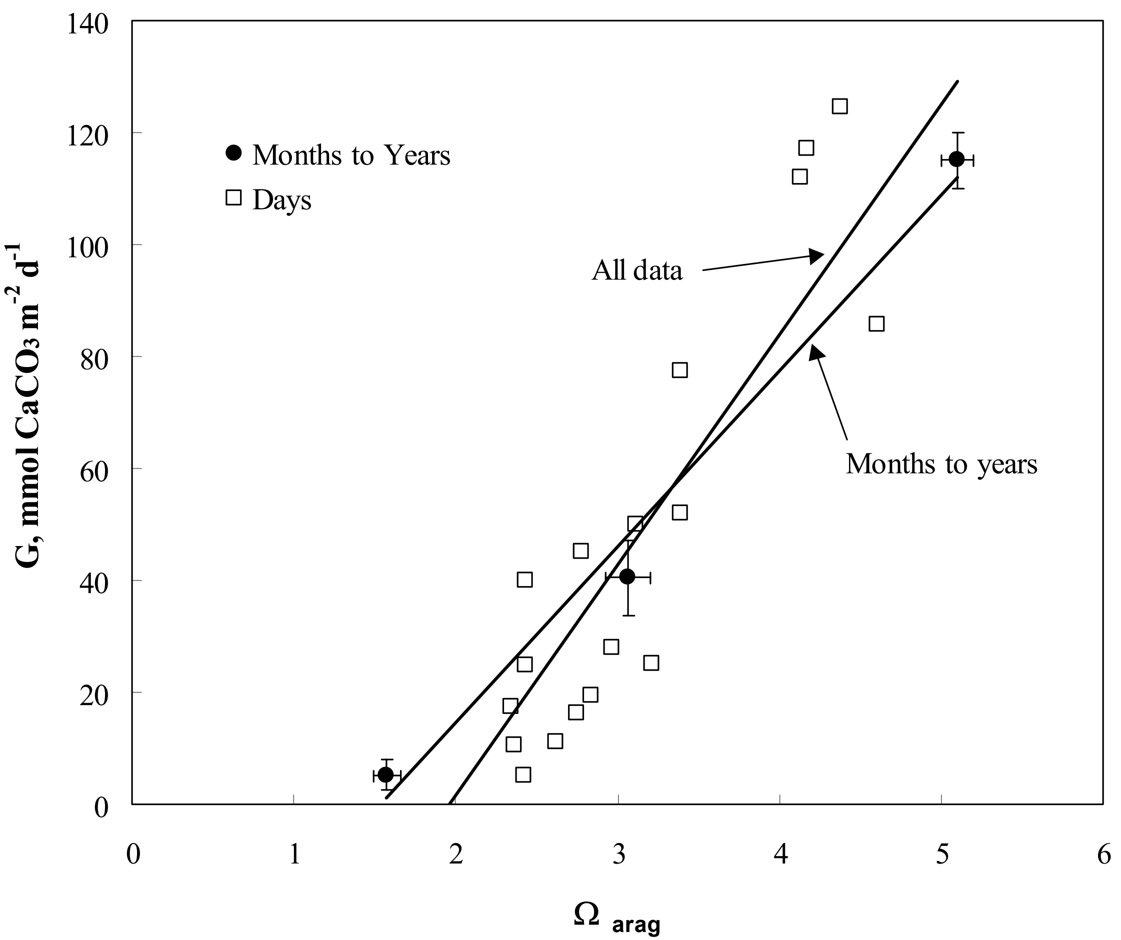
Site of carbonate production study by Broecker and Takahashi in 1962-63.

Comparison of normalized carbonate production rates on the Great Bahama Banks and Biosphere 2 mesocosm



Great Bahama Banks data from Broecker and Takahashi 1966.

Comparison of short and long term response of B2 coral reef mesocosm to periods of elevated CO_2 (low Ω)



Ecosystem exhibits little ability to acclimate to prolonged stress of elevated CO_2.

Effect of a doubling in CO_2 (350-700 μatm) on calcification, (% decrease)

<u>Calcareous macroalgae</u>

Amphiroa foliacea	-36	Borowitzka, 1981
Porolithon gardineri	-16	Agegian, 1985
Corallina pilulifera	-44	Gao et al., 1993

<u>Corals</u>

Stylophora pistillata	-3	Gattuso et al., 1998
Porites porites	-16	Marubini & Thake, 1999
Porites compressa	-27	Marubini et al., 2001
Acropora sp.	-37	Schneider & Erez, 2000
Porites/Montipora	-50	Langdon & Atkinson, in prep.

<u>Coccolithophorids</u>

Emiliania huxleyi	-10	Riebesell et al., 2000
Gephyrocapsa oceanica	-29	" "
Natural pop. (N. Pac.)	-38	" "
Emiliania huxleyi	*-17*	Zondervan et al., 2001
Gephyrocapsa oceanica	*–29*	" "

<u>Community</u>

Biosphere 2	-40	Langdon et al., 2000
Monaco mesocosm	-21	Leclercq et al., 2000
Bahama Bank	-30	Broecker & Takahashi, 1966

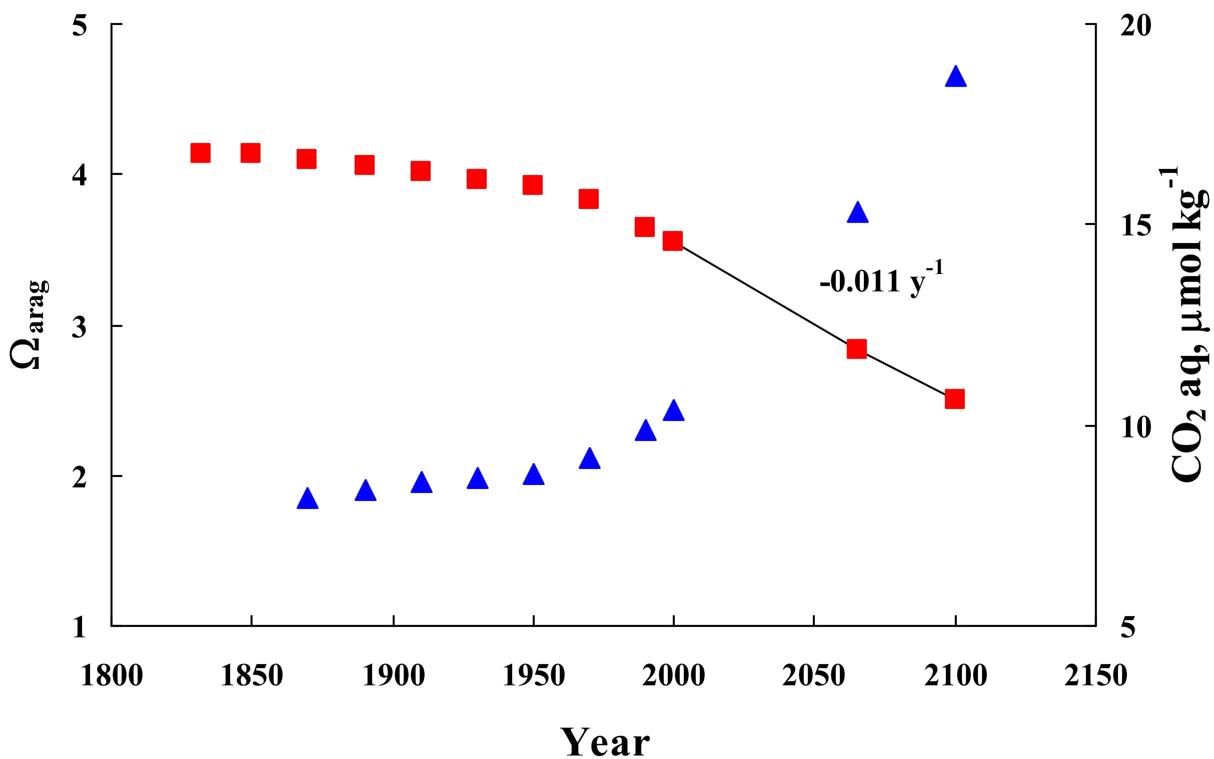
Average decrease for all these species and systems is –28%.

Link between atmospheric CO_2 and the rate of calcification

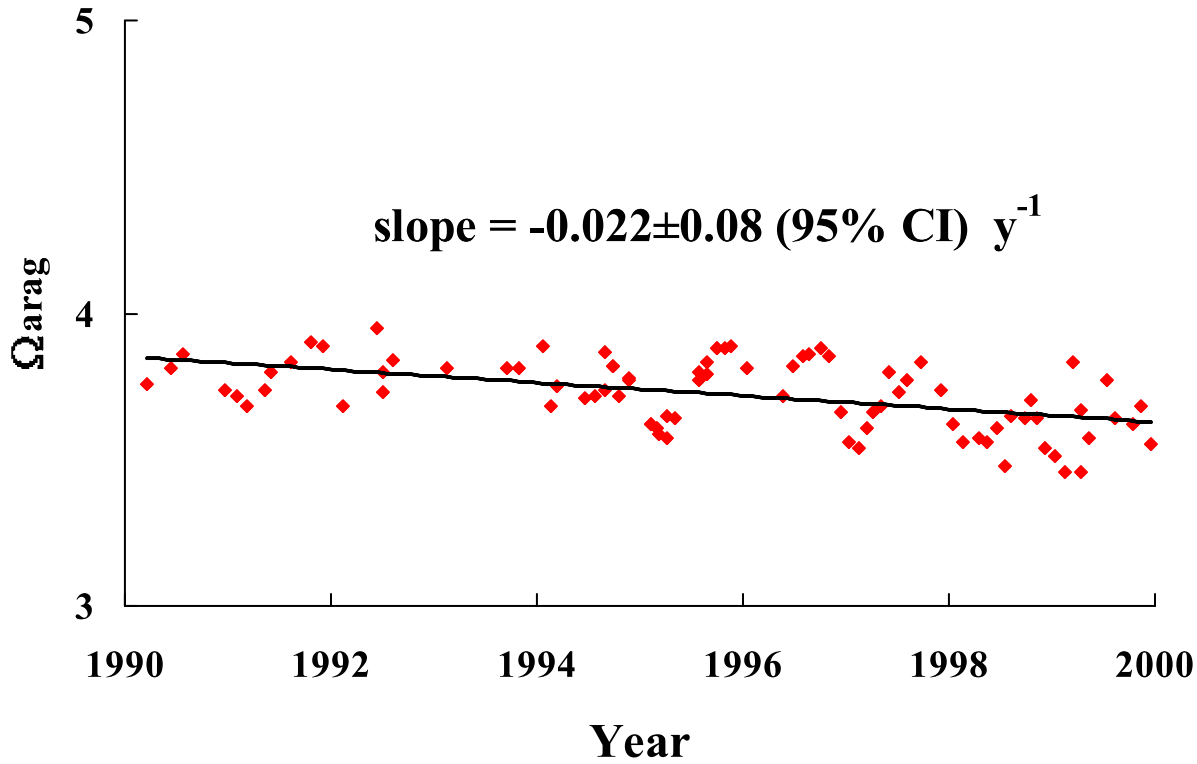
- $CO_2 + CO_3^{2-} + H_2O \leftrightarrow 2HCO_3^-$
- $\Omega_{arag} = [Ca^{2+}][CO_3^{2-}]/K_{sp}$
- $R = k(\Omega-1)^n$

Calculated changes seawater carbonate chemistry

(assuming IS92a business a usual scenario, S=35, TA=2300)



Observations at the Hawaii Ocean Time Series Station



Time line of CO_2 treatments